

SUNY College Cortland

## Digital Commons @ Cortland

---

Master's Theses

---

1-2017

### The validity of height as a determinant of takeoff distance to hurdle one in NCAA Division III hurdlers

Phillip Wiltshire

Follow this and additional works at: <https://digitalcommons.cortland.edu/theses>



Part of the [Exercise Physiology Commons](#), [Exercise Science Commons](#), [Sports Sciences Commons](#), and the [Sports Studies Commons](#)

---

#### Recommended Citation

Wiltshire, Phillip, "The validity of height as a determinant of takeoff distance to hurdle one in NCAA Division III hurdlers" (2017). *Master's Theses*. 37.  
<https://digitalcommons.cortland.edu/theses/37>

This Open Access Thesis is brought to you for free and open access by Digital Commons @ Cortland. It has been accepted for inclusion in Master's Theses by an authorized administrator of Digital Commons @ Cortland. For more information, please contact [DigitalCommonsSubmissions@cortland.edu](mailto:DigitalCommonsSubmissions@cortland.edu).

The Validity of Height as a Determinant of Takeoff Distance

to Hurdle One in NCAA Division III Hurdlers

by

Phillip Wiltshire

Submitted in Partial Fulfillment of

The Requirements of the Master of Science in Exercise Science Degree

Kinesiology Department

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

Approved:

\_\_\_\_\_  
Date

\_\_\_\_\_  
Peter McGinnis, Ph.D.  
Thesis Advisor

\_\_\_\_\_  
Date

\_\_\_\_\_  
John T. Foley, Ph.D.  
Committee Member

\_\_\_\_\_  
Date

\_\_\_\_\_  
Erik Lind, Ph.D.  
Committee Member

\_\_\_\_\_  
Date

\_\_\_\_\_  
Eileen Gravani, Ph.D.  
Associate Dean, Professional Studies

## ABSTRACT

The purpose of this study was to determine if the relationships between the height of a hurdler and the takeoff distance to the first hurdle for men and women as reported by Frye (2008) were valid for NCAA Division III 100 m and 110 m hurdlers. With no specific research reported to validate Frye's data, it is unclear how the suggested takeoff distances were developed. It is also unclear whether hurdler height or another factor is the main determinant of takeoff distance for the high hurdlers. Participants in this study were three female 100 m hurdlers and four male 110 m hurdlers all of whom competed on an NCAA Division III institution's varsity track and field team. Each participant ran three trials of the first 25 m of a hurdle race, from the starting blocks through clearance of the second hurdle. A stationary video camera recorded a sagittal view of the each participant. The camera field of view included the last approach step to the first hurdle, the clearance of the first hurdle, and the first step after hurdle clearance. The takeoff distances to the first hurdle were measured using the Tracker video analysis software and the average of each hurdler's takeoff distances were calculated. The predicted takeoff distance for each athlete were determined using a linear regression equation derived from Frye's (2008) data. The difference between the predicted and average takeoff distances for each participant were then compared to the participant's best 100 m or 110 m hurdle race time expressed as a percentage of the world record for the event. For the male participants, there was a strong positive relationship between the difference between the predicted and average takeoff distances and the participant's best time as a percentage of the world record time. The linear correlation coefficient between these two variables for the men was .921. For the female participants, the relationship between these two variables was weaker and negative. The linear correlation

coefficient between these two variables was  $-.474$  for the women. In conclusion the results suggest that the relationship between hurdler height and takeoff distance as presented in Frye's chart is valid for male hurdlers at the NCAA Division III level but its validity for female hurdlers is not supported.

## TABLE OF CONTENTS

	Page
ABSTRACT .....	iii
TABLE OF CONTENTS .....	v
LIST OF TABLES AND FIGURES .....	vii
CHAPTER 1 INTRODUCTION .....	1
Statement of Problem .....	2
Purpose of the Study .....	3
Hypotheses .....	3
Delimitations .....	3
Limitations .....	4
Assumptions .....	5
Significance of the Study .....	6
Definition of Terms .....	6
CHAPTER 2 REVIEW OF LITERATURE .....	8
Takeoff Distance from Hurdle .....	8
The First Hurdle .....	15
Height of Center of Mass Over the Hurdle .....	16
Vertical Velocity of COM at Takeoff .....	17
Takeoff Foot Contact Time .....	17
Landing Distance from the Hurdle .....	19
Horizontal Distance from COM to Foot at Landing .....	20
Summary .....	20
CHAPTER 3 METHODS .....	21
Participants .....	21
Informed Consent .....	22
Variables .....	22
Data Collection Setup and Procedure .....	23
Data Reduction .....	26
Statistical Analysis .....	28
CHAPTER 4 RESULTS .....	30
Males .....	30
Females .....	31
Combined Results .....	33
CHAPTER 5 DISCUSSION AND CONCLUSIONS .....	34
Discussion .....	34
Conclusion .....	37
REFERENCES .....	39

APPENDICES .....	42
A. SUNY Cortland Institutional Review Board Approval Letter .....	42
B. Informed Consent .....	44
C. High Hurdle Warm Up .....	45
D. Reproduction of Frye's (2008) Original Chart of "Model Takeoff Distance" .....	46
E. Frye's (2008) Chart Entries Plotted.....	47

## LIST OF TABLES AND FIGURES

### TABLES

1. Hurdler Heights and Takeoff Distances .....	9
2. Characteristics of Participants .....	28
3. Results for All Participants and Trials.....	32
4. Reproduction of Frye's (2008) Original Chart of "Model Takeoff Distance" .....	46

### FIGURES

1. Data collection set up showing the configuration of the camera relative to the hurdle and hurdle lane .....	24
2. The Tracker screen showing the video window, the x and y coordinate axes, digitized toe, and toe coordinates .....	28
3. Difference between predicted and actual takeoff distances vs. percent difference in PR to world record for men and women participants.....	35
4. Takeoff distance versus hurdler height for men hurdlers based on values derived from Frye's (2008) chart .....	47
5. Takeoff distance versus hurdler height for women hurdlers based on values derived from Frye's (2008) chart .....	47

## CHAPTER 1

### INTRODUCTION

In track and field, the high hurdles are an event that is unique in its demands and requires a distinct skill set for success. Despite the change from yards to meters, the event remains unchanged in hurdle height in over 130 years. The hurdles are unique in that the fixed distances between the hurdles force the hurdler to have a predetermined step count. Faster times are the goal of a hurdler and since there are ten barriers (100 m and 110 m hurdles) the effective navigation of these barriers becomes an integral component to the times of a hurdler. This race, like many others in track and field, is measured by the time it takes an athlete to reach the finish line.

Many different factors have been measured when trying to analyze a hurdler's movement. One of the common parameters that is measured is the hurdler's takeoff distance. This is defined as the distance to the base of the hurdle from the toe of the takeoff foot at takeoff for the hurdle clearance (Coh & Iskra, 2012; Dapena & McDonald, 1991; Frye, 2008; Lindeman, 2008; Mann, 2011; Mann & Hermam, 1985; McFarlane, 1998; Winckler, 1994). These researchers, however, suggest different optimal takeoff distances and claim different factors as the determinant of this optimal takeoff distance.

Frye (2008) provides a chart which suggests the optimal takeoff distances for hurdlers based on his or her height. It is not clear from where the information for this chart was derived nor has the validity of this chart been established. Thus, an investigation of Frye's (2008) chart of takeoff distances is warranted. This study examined the difference between the takeoff distances of hurdlers and their predicted takeoff distances as determined from a



linear regression equation derived from data presented in Frye's chart (2008). This difference was then compared to the hurdlers' fastest times in the event expressed as a percentage of the world record. Only takeoff distances to the first hurdle was used in analysis. The approach to the first hurdle is different from the approach to the other hurdles. The approach to the first hurdle typically requires an eight step run up from the starting blocks rather than the typical three-step approach used between the remaining hurdles in the race (Mann & Herman, 1985; McDonald & Dapena, 1991a). The first hurdle also sets up the race and allows the athlete to get into a rhythm (Winckler, 1994). This is why the first hurdle was used in this study to evaluate Frye's (2008) takeoff distance chart.

### **Statement of the Problem**

Hurdling has been investigated by many different researchers in an attempt to determine the factors related to faster hurdling times. Mann (2011) established specific criteria for hurdlers to be considered poor, average, and elite, but only if the hurdlers could achieve a certain "optimal" velocity. Frye (2008), Mann (2011), Čoh and Iskra, (2012) McFarlane (1988; 1993), and Tidow (1997) presented direct descriptors for the correct navigation over the hurdles in race situations. One of the most studied descriptors is the takeoff distance of the athlete. Even though many researchers agree that the takeoff distance is important, there is little consensus as to the optimal takeoff distances and even more disagreement as to the determinants of the proper takeoff distance. The velocity of the athlete (Mann, 2011), the speed of the lead leg swing (McFarlane, 1988; 1993), and the height of the athlete (Frye, 2008; Čoh & Iskra, 2012; Tidow, 1997) have all been identified as the most important factor in determining the takeoff distance of a hurdler. Frye (2008) developed a chart that clearly identifies the optimal takeoff distances of athletes according to

his or her height. This chart has yet to be validated. Frye has coached Olympic hurdlers, including some of the top 10 males of all time in the high hurdles. Without any specific research reported to validate this chart, it is unclear how he developed the optimal takeoff distances. It is also unclear whether height of the athlete or one of the other factors listed is the main determinant of takeoff distance for hurdlers.

### **Purpose of the Study**

The purpose of this study was to determine if the relationships between the height of a hurdler and the takeoff distance to the first hurdle for men and women as reported by Frye (2008) were valid for NCAA Division III 100/110 m hurdlers. Frye presented these relationships in tables listing hurdler heights and the corresponding takeoff distances for male and female hurdlers. Determining if the relationships provided by Frye are valid for NCAA Division III level hurdlers will be useful to athletes who compete at this level and their coaches.

### **Hypothesis**

It is hypothesized that as the difference in predicted takeoff distance and actual takeoff distance decreases, the difference between their personal record time (PR) and the world record, expressed by a percentage of the world record, will also decrease.

### **Delimitations**

The participants performed trials during practice rather than competition. A trial consisted of a run through the first 25 m of a hurdle race from the starting blocks to clearance of the second hurdle.

Both male and female hurdlers were used as participants in the study because takeoff distances were listed for different heights of both sexes in Frye's chart (2008).

The athletes were filmed on a 400 m outdoor track. A single stationary video camera was used to record the participants as they approached and cleared the first hurdle. The takeoff distances were measured from the video using two-dimensional video analysis techniques.

Only the takeoff distance to the first hurdle was measured. In the hurdling race every hurdle sets the athlete up for the next hurdle. If a hurdler cannot perform the movement correctly over the first hurdle then the hurdler must find a way to make up for that during the rest of the race. This suggests that the first hurdle may be the most important one in the race (Mann, 1985; McDonald & Dapena, 1991a), and the successful navigation of it can greatly improve the overall performance of the athlete. However, two hurdles were set up to ensure that the athletes had something to push for so they did not shut down their effort during the hurdle clearance. Participants were instructed to run as if they were in a competition.

### **Limitations**

The motivation of the participants may have affected the results in this study. The athletes were not filmed during a competition so they did not have the extra motivation to beat their opponent or produce a best time. This was somewhat controlled by urging the athletes to do their best and imitate race like situations as much as possible during filming. This included having them do the same warm up that they would do during a race and having them start the same way they would during a race (from blocks and from normal start commands). Also, data was collected during the week of the conference meet, so, the athletes were more motivated and focused during their practice time. This was one of the most important meets for them.

The sample size for this study was small. The problem with this limited sample size was that the correlations have to be much stronger to establish any significance. The participants had a wide range of hurdling ability and experience. The hurdle age (the number of years of hurdling experience a participant has prior to filming) was very young for a few of the participants.

### **Assumptions**

It is assumed that the population used for Frye's (2008) original chart were high level collegiate athletes and professional athletes. There was no information provided with the chart to confirm this and attempts by the researcher to contact Frye were unsuccessful.

The health and fitness of the participants was assumed to be at the highest level at the time of data collection.

Peaking was planned during this phase of the participants' training. All of the participants ended their outdoor competition season within a few weeks of filming. It was assumed that the participants were at their peak hurdling performance level at the time of data collection.

It was assumed that each participant understood and was competent in completing the warm up routine prior to data collection. It was also assumed that each participant was competent at hurdling. Data collection occurred during the end of the outdoor season for all of the participants. They had all participated in the full indoor and outdoor intercollegiate track and field season for that year. The first practice for the indoor track and field season began in mid-October and the data collection occurred in early May.

## Significance of the Study

The purpose of this study was to determine if the relationships between the height of a hurdler and the takeoff distance to the first hurdle for men and women as reported by Frye (2008) were valid for NCAA Division III 100/110 m hurdlers. At a coaches conference in 2008, Frye presented these relationships in tables listing hurdler heights and the corresponding takeoff distances for male and female hurdlers. Understanding if the relationships provided by Frye (2008) are valid for NCAA Division III level hurdlers will be useful to coaches and athletes competing at this level.

## Definition of Terms

<i>Block Start</i>	A common start of a sprinting track race from a downward position with the feet of the athlete up against starting blocks
<i>COM</i>	The abbreviation for center of mass. Center of mass is the point of a body where the mass of the body is equally distributed in every direction from that point
<i>High Hurdles</i>	A race in track and field (known as the 110 m hurdles for men, or 100 m hurdles for women) in which there are ten barriers, or hurdles, set up at a height of 42 inches for men and 33 inches for women
<i>Horizontal Velocity</i>	The movement of the COM of the athlete in the horizontal direction expressed in meters per second
<i>Lead Leg</i>	The first leg of the athlete to go over the hurdle
<i>Recovery Step</i>	This refers to the first step from the trail leg to the lead leg following the hurdle clearance

<i>Takeoff Distance</i>	The horizontal distance in meters from the toe of the takeoff foot to the front of the hurdle
<i>Trail Leg</i>	The second leg of the athlete to go over the hurdle. It is also the takeoff leg of the athlete before the hurdle
<i>Years Hurdling</i>	This is the number of years that a participant has trained as a hurdler

## CHAPTER 2

### LITERATURE REVIEW

The purpose of this study was to determine if the relationships between the height of a hurdler and the takeoff distance to the first hurdle for men and women as reported by Frye (2008) were valid for NCAA Division III 100/110 m hurdlers.. This literature review includes research examining the importance of takeoff distance and the suggested optimal takeoff distances for both male and female hurdlers. Research regarding other factors affecting hurdling performance is also included in this review.

#### **Takeoff Distance from the Hurdle**

The first component of hurdle clearance is the take-off distance from the hurdle. This is defined as the horizontal distance from the toe of the takeoff foot to the base of the hurdle at the moment that the athlete leaves the ground. Takeoff distance is one of the most commonly measured variables in the hurdle movement and many coaches and researchers have highlighted its importance. Winckler (1994) lists a variety of reasons for improper hurdle movements, reasons that they happened, and corrections. Being too high over the hurdle, loss of horizontal velocity, too much vertical velocity, and other effects have all been attributed to incorrect takeoff distances during the hurdle movement, thus establishing the importance of takeoff distance in the hurdle movement. Tidow (1992) provides a list of important performance characteristics for a hurdle race and identifies the optimal takeoff point as one of the top metrics. The Level 2 certification handbook provided by USA Track and Field (USATF) Coaching Education Program states that “The number one problem for all hurdlers is the takeoff” (Winckler, Shaver, & Schexnayder, 2003, p. 43), an opinion also

held by other researchers (Mann & Herman 1985; Mann, 2011; McDonald & Dapena, 1991a; McFarlane, 1988, 1993; Frye, 2008; Čoh & Dolenec, 1995). While these researchers agree that takeoff distance is important, they fail to agree on why it is important and what the optimal takeoff distance should be.

Frye (2008) believed that hurdler height was the main factor in determining the proper takeoff distance. Mann (2011) partially agrees, stating, “The take-off distance from the first hurdle largely depends on the velocity of the athlete at take-off and the height of the athlete” (p. 22). He added, however, the extra factor of the velocity of the athlete. The purpose of the present study was to validate the chart developed and presented by Frye (2008). Table 1 is derived from Frye’s (2008) chart. Frye’s (2008) original chart was in feet and inches. Each entry in Frye’s chart included a range of heights with a range of suggested takeoff distances for each height range. Table 1 lists only the median values of the ranges for each entry and this median value was converted from feet and inches to meters. The resulting chart is Table 1. Frye’s (2008) original chart can be found in Appendix D.

Table 1

<i>Hurdler Heights and Takeoff Distances</i>			
Males		Females	
Height (m)	Takeoff (m)	Height (m)	Takeoff (m)
1.600	2.311	1.600	2.007
1.651	2.286	1.651	1.981
1.702	2.261	1.702	1.956
1.753	2.235	1.753	1.930
1.803	2.201	1.803	1.892
1.854	2.184	1.829	1.842
1.905	2.146		
1.956	2.134		

*Note: Derived from Frye’s (2008) original chart which is presented in full in Appendix D.*

Frye (2008) did not explain how he developed the relationship between hurdler height and takeoff distance which was presented in his chart. Frye has coached multiple elite



hurdlers including NCAA champions, Olympians, Olympic medal winners and world record holders. Even though Frye (2008) presented no evidence for the relationship between hurdler height and takeoff distance, his pedigree as a coach makes the information he presented credible. Examining the validity of the relationship between hurdler height and takeoff distance is the focus of the present study.

Other researchers have measured the takeoff distances of hurdlers and presented suggestions as to the proper takeoff distances for both males and females. Mann and Herman (1985) examined hurdlers at hurdle 9 in the 1984 Olympic Games. They recorded the first, second, and eighth place finishers in the women's final and compared different kinematic variables, including the takeoff distances and height of each athlete. The takeoff distances and heights reported by Mann and Herman do not align with the suggested takeoff distances listed in Frye's (2008) chart. The first place hurdler had a takeoff distance of 2.21 m while measuring 1.78 m for her height. This is much longer than the suggested takeoff distance of between 1.83 m and 1.96 m for her height. This pattern continues for the second place hurdler who had a 2.08 m takeoff distance and a height of 1.73 m. Her takeoff distance was longer than the range for her height suggested in the Table 1. The eighth place finisher had a 2.06 m takeoff distance and a height of 1.83 m. Her takeoff distance was also outside the suggested range for her height. None of the hurdlers' takeoff distances fell within the ranges suggested for their height by Frye (2008).

Čoh and Dolenec (1996) measured the kinematics of world-class hurdler Brigita Bukovec for a 12.75 s 100 m hurdle race. Her takeoff distances in this race were 2.16 m and 2.08 m at hurdles 4 and 5 respectively. Her height is 1.68 m which, so, according to Frye's

(2008) chart, her takeoff distance should be between 1.93 m and 2.01 m. Her takeoff distances were outside the range predicted for her height.

All of these athletes were female so maybe the male side of the chart will prove to be more accurate. Čoh and Iskra (2012) looked at the kinematics of four sub-elite male hurdlers over the 4<sup>th</sup> hurdle. The experimental setup simulated a 110 m hurdle race but only the first five hurdles were used. The athletes ran three trials through the five hurdles and were recorded using infrared cameras. The athletes' kinematics were then measured using video analysis software. The take-off distances from the fourth hurdle were (in order of fastest to slowest times for the race recorded) 2.36 m, 2.27 m, 2.32 m, and 2.27 m. The fastest hurdler had the longest takeoff distance, the lowest take-off angle, and the shortest time over the hurdle. This suggests that there is a strong relationship between takeoff distance and horizontal velocity. Unfortunately, the heights of the athletes in this study were not listed.

Although Frye (2008) suggested that the height of the athlete is the most important determinant of takeoff distance, other researchers have suggested alternate determinants of hurdle takeoff distances. Lindeman (2008) suggested that the velocity of the athlete is a more important determinant of the takeoff distance. Lindeman (2008) did not describe the theoretical basis for this, however. The velocity of the athlete certainly determines takeoff distance and could be accounted for in the ranges that Frye (2008) listed for each height of athlete. McFarlane (1988) states in his book "The athlete's distance from the hurdle on takeoff will depend on several factors: speed of the approach run, length and speed of the lead leg, height of the athlete's and the hurdle, flexibility of the hip and knee joints, type of track surface, weather conditions, previous hurdle clearance, and the athlete's kinesthetic 'feel' for the hurdle" (p. 9). This lists many variables that influence takeoff distance but does

not suggest which of the variables is the most important. Height and length of lead leg, which should relate to height, are listed. McFarlane (1988) goes on to say that “Taller hurdlers can afford to get closer to the hurdle since they do not have to raise their center of gravity as high in clearance as the shorter hurdlers” (p. 11). This supports the data in Frye’s (2008) chart, that as the hurdler height increases, the takeoff distance decreases. This also suggests that McFarlane (1988) believes that the height of the athlete is one of the more important determinants of takeoff distance, since this is the only one that he expanded upon in this section of his book. The USATF Level 2 certification handbook says “Anthropometric considerations must be made in determining the correct distance from the hurdle for takeoff” (Winckler et al., 2003, p. 43). This suggests that the authors believe there are many variables (such as McFarlane (1998) suggested) but they do not expand on which ones are more important. Winckler (1994) nearly echoed what the Level 2 training book suggests in his presentation at a track and field summit saying “Anthropometrical considerations must be made in determining the correct takeoff distance from the hurdle.” Mann and Herman (1985) examined hurdlers competing in the 1984 Olympic Games and suggested that it may be the length of the lead leg that is the most important aspect in takeoff distance. Leg length should relate to the height of the athlete. Another suggestion from Mann and Herman (1985) is that the speed of the lead leg swing would be the determining factor to the takeoff distance from the hurdle. This would make sense if the hurdler can swing the leg up faster to clear the hurdle then they would be able to takeoff closer to the hurdle. While many of these factors could affect the takeoff distance, the height of the athlete will be the only variable examined in the present study.

The biggest disparity in the research concerns the suggested takeoff distances for optimal performance. Each researcher that measured takeoff distances also provided what they thought the optimal distance was for both men and women. Mann (2011) measured the kinematics of many elite hurdlers, including their takeoff distances. Mann listed what he found (through his previous research, including his 1991 study) to be good, average, and poor takeoff distances. In order from good to poor he lists the takeoff distances to be 2.40 m (7'10), 2.46 m (8'), and 2.51 m (8'2) for men and 1.94 m (6'4), 2.0 m (6'6), and 2.06 m (6'9) for females. If these distances are comparable to distances in Frye's (2008) chart. Mann (2011) did not list any hurdler heights but he does indicate that the hurdlers need to be at a certain "golden" velocity for these takeoff distances to be optimal. This suggests that he believes the horizontal velocity is the most important factor for takeoff distance. He also indicated that minimizing the hurdle stride as a whole was important. Mann (2011) continues on to say that the takeoff distance is the most important in the results because a deviation from the proper takeoff distance will cause the hurdler to jump too high, or reach too much in the hurdle stride. This is an opinion echoed by other researchers (Čoh & Iskra, 2012; Lindman, 2008; Tidow, 1997; McDonald & Dapena, 1991a; McFarlane, 1988 & 1993; Winckler, 1994).

Winckler (1994) suggests that the takeoff distance should be approximately 2.0 m (6'6) from the hurdle but does not indicate whether this is for a male or female hurdler. He later lists in a chart that the takeoff distance for women should be 2.05 m (6'8) throughout the race. This would lead the author to believe that either the 2.0 m takeoff distance estimate is for males or that it is just an approximation between what Winckler believes is the takeoff distance for both males and females. While both of these suggestions fall within the range of

takeoff distances in Frye's (2008) chart they are not very useful without any information about height or sex.

Tidow (1997) suggests an optimal takeoff distance range of 2.1-2.2 m (6'10"-7'2") for male hurdlers. This range of takeoff distances is nearly identical to the range that Frye (2008) lists for a hurdler with a height of 6'3".

The USATF Level 2 coaching certification manual (Winckler et al., 2003) also lists 2.1-2.2 m as the suggested takeoff distance for males. They also list the suggested takeoff distance for females as 1.8-2.0 m (5'10"-6'6"). This suggested distance for women encompasses nearly all the distances that Frye (2008) lists on his chart. It leaves a little bit of the range out for 5'5" and 5'3" female hurdlers, but it is very rare to see elite level female hurdlers that are that short.

Grimshaw, Marar, and Salo (1995) studied of 40 developmental to elite hurdlers in Britain and measured takeoff distances. They filmed primarily over the third hurdle of the race and filmed many of the races for these athletes over the course of a few years. They used these data to come up with a suggestion for the takeoff distances of 2.0 m-2.2 m (6'6"-7'2") for both males and females. This leaves a large portion of the chart by Frye (2008) out. One thing that may be a problem with the study is the large range of ability of the subjects. Grimshaw, et al. (1995) did not clearly describe what distinguished a developmental hurdler from an elite hurdler.

McFarlane (1988).suggested that the takeoff distance for males should be between 2.0 m and 2.2 m (6'6" and 7'2") and 1.95 m and 2.10 m (6'4" and 6'10") for females. He is also the only researcher to suggest that the optimal distance varies within the race with the speed of the athletes saying "As speed increases so does the takeoff distance"(1988, p. 12). This

means that as an athlete accelerates to their top speed they should be further away from the hurdle and as they decelerate near the end of the race they should be closer. This also aligns with the suggestion from other researchers that the velocity of the athlete is important when estimating optimal takeoff distance.

The results of the reviewed studies and the opinions of the prominent coaches listed above clearly indicate that the takeoff distance of athletes is an important hurdling feature to examine. What is unclear is what determines the takeoff distance and what takeoff distance is optimal. The “perfect” distance may be dependent on the individual, their velocity, their flexibility, their height, or other variables. The present study was only concerned with one of these variables, height of the athlete and its effect on takeoff distance as shown in the chart developed by Frye (2008).

### **The First Hurdle**

Over the course of a hurdle race there are ten barriers that the hurdler must successively navigate, so why focus on only the first hurdle? Each successive hurdle clearance is dependent on the correct navigation of the previous hurdle. Some coaches only have their athletes practice over the first few hurdles because they believe anything that they do incorrectly will manifest itself there and must be corrected in order for the athlete to correctly run the remainder of the race. A prominent coach for the Canadian National Track and Field team, McFarland (1988), considers each phase of the hurdle race to be dependent on attaining the maximum speed over the start and first two hurdles. This is achieved through the optimal start of the athlete, but more importantly it is achieved by their ability to maintain that starting velocity over the hurdle. This means that the clearance of the first hurdle puts the athlete in position to be successful over the rest of the race.

### **Height of Center of Mass Over the Hurdle**

When a hurdler clears a hurdle, his or her center of mass (COM) travels in a parabola over the hurdle. A hurdler must to vertically displace his or her COM upward in order to get over the hurdle. This causes the hurdler to deviate from proper sprinting mechanics during the hurdle stride (Mauroy, Schepens, & Willems, 2014). The smaller the vertical displacement and the closer the COM is above the hurdle leads to less time spent in the air so the quicker a hurdler can get back to the ground. While in the air the hurdler is not able to apply force to the ground and accelerate. There are two ways to look at this: 1) height of the COM at the moment it is over the hurdle, or 2) height of the COM at its apex, whether it is right over the hurdle or slightly in front of it or behind it. The former of the two provides the researcher with the most useful information on the hurdling movement.

Frye (2008) suggested that there is a linear relationship between hurdle clearance heights and final times. Frye (2008) goes as far to say that “Clearance is key!” What Frye (2008) indicates that, if a hurdler ran the same velocity between the hurdles, clearance heights would determine the race times. Lower clearance heights produce faster race times. What Frye (2008) really shows is that staying as close to the hurdle without hitting it is important to the success of the race, but what is unclear is how exactly to achieve this. The answer may lie in one of the other parameters being examined.

McDonald and Dapena (1991a) looked at the kinematics of hurdlers competing in the 1988 U.S. Olympic Trials. One of the components that they examined was the height of the COM of the hurdlers at different points during hurdling. The mean COM height at its apex for the men was  $1.347 \pm .023$  m. The mean of the COM height at its apex for the women was  $1.193 \pm .033$  m. These values are a good benchmark for the maximum COM heights for both

men and women elite hurdlers. The four male hurdlers studied by Čoh and Iskra (2012) had a mean COM height at apex of  $1.20 \pm .01$  m. These four hurdlers were not elite hurdlers and their COM heights at apex are much different than the COM heights at apex for the elite hurdlers studied by McDonald and Dapena (1991a). The difference is 14 cm or almost 6". This theoretically could make a huge difference in the airtime of the athletes and thus in the overall time of their race. The height reached by the COM of a hurdler during hurdle clearance may be the most important factor in determining clearance time and final time of a hurdler.

### **Vertical Velocity of COM at Takeoff**

In order to clear the hurdle the athlete must raise their COM over the top of the hurdle. This requires them to produce vertical velocity in order to displace their COM above the hurdle. This production of vertical velocity at takeoff causes a loss in horizontal velocity as well as keeps the athlete in the air where they can not apply force to the ground. This means that vertical velocity should be minimized as much as possible while still displacing the COM of the athlete over the hurdle. Mann and Herman (1985) suggested that athletes need to minimize the vertical velocity of their hurdling movement as much as possible. Hay (1985) says that the vertical velocity of the athlete at takeoff is directly related to the height of the COM over the hurdle. There is not a specific velocity that should be achieved at takeoff because it largely depends on the height of the hurdler and how much they lower their COM in preparation for the hurdle clearance.

### **Takeoff Foot Contact Time**

Takeoff foot contact time refers to the amount of time that the takeoff foot, the foot of the trail leg, maintains contact with the ground in preparation for takeoff. It is during this



time that the hurdler converts some of their horizontal velocity into vertical velocity. The takeoff foot contact time can also be thought of as the braking phase of the stride (because is braking of the horizontal velocity of the athlete occurs during this phase). It is theorized that a shorter braking phase would keep the athlete moving at a faster horizontal velocity, thus producing a quicker hurdle clearance and race. Finch, Ariel, and McNichols (2000) measured the takeoff foot contact times of four 110m hurdlers at the 2000 U. S. Olympic Trials. The results indicated that the shorter the takeoff foot contact time, the shorter the flight time and the faster the overall race time. The four hurdlers studied by Finch et al. (2000) had foot contact times of 0.150 s, 0.133 s, 0.133 s, and 0.150 s. The corresponding flight times for these hurdlers were .333 s, 0.302 s, 0.300 s, and 0.333 s. The two hurdlers with the shortest ground contact times, 0.133 s and 0.133 s, also had the shortest flight times, 0.302 s and 0.300 s.

Čoh and Iskra (2012) also measured takeoff foot contact times, but the hurdlers they studied were sub-elite hurdlers. The four hurdlers they studied had takeoff foot contact times (in order of fastest overall time to the slowest) of 0.132 s, 0.147 s, 0.143 s, and 0.134 s. Clearance times were not reported.. The hurdler with the shortest takeoff foot contact time had the fastest overall time.

The relationship between takeoff foot contact time and race time was also mentioned in a study by Mann and Herman (1985). They compared the kinematics of the gold and silver medalists in the 110 m hurdles at the 2004 Olympic Games to the 8<sup>th</sup> place finisher in that event. One of the variables examined was the takeoff foot contact time of the hurdlers. The gold and the silver medalists both had takeoff foot contact times of 0.12 s, while the 8<sup>th</sup> place hurdler had a takeoff foot contact time of 0.14 s. Mann and Herman (1985) state,

“Thus, the difference between the two top medals was determined in part over the hurdle, while a medal possibility was lost by the eighth-place finisher, due in part to poor ground time results” (p. 13). With this statement the researchers clearly indicate that poor ground contact time negatively affected the 8<sup>th</sup> place finisher’s performance in the hurdle race.

### **Landing Distance from the Hurdle**

Landing distance from the hurdle has been measured in nearly every biomechanical study of hurdle clearance. The landing distance from the first hurdle is largely determined by the takeoff distance from the first hurdle, velocity going into the hurdle, and takeoff angle of the COM. The athlete wants to land as closely to the hurdle as they can to minimize the time in the air. As discussed before an athlete can not apply force against the ground and therefore can’t accelerate while in the air, so it is important to get back to the ground as quickly as possible. Čoh and Iskra (2012) reported the landing distance from the first hurdle for four 110 m hurdlers. The landing distances for the four hurdlers were 1.28 m, 1.19 m, 1.39 m, and 1.42 m. These landing distances are listed in order from the fastest hurdler to the slower hurdler. There does not seem to be a strong relationship between landing distance from the first hurder and the final time of the hurdler.

Frye (2008) presented a table of suggested landing distances from the hurdles for different hurdler heights. Frye suggests that these landing distances are ideal landing distances for the specific hurdler heights listed, but they may not be achieved by everyone. It is not possible to compare the landing distances in Frye’s (2008) study with those reported by Čoh and Iskra (2012) since Čoh and Iskra did not report the hurdler heights. Landing distance seems to be a variable that is dependent on several other variables such as takeoff distance, takeoff angle, and both vertical and horizontal velocities.

### **Horizontal Distance of from COM to Foot at Landing**

The landing phase of the hurdler is very tricky because the hurdler has to time the placement of the lead leg onto the track while maintaining a slight forward lean in order to put themselves back in sprinting position. As discussed before, the distance from the COM to the support foot is an important aspect of sprinting mechanics. Since the hurdlers are required to sprint between the barriers, it is also important for their race. The hurdlers want to set themselves up to start sprinting as soon as they hit the ground and this requires them to land “with their foot under them”, or with their foot as close to their COM as possible. Tidow (2012) says that this landing phase should be as quick as possible and is made quicker by contacting the ground as close horizontally to the COM as possible. He says that elite hurdlers contact the ground within 3-11 cm of their COM, good hurdlers within 19 cm, and other hurdlers within 29 cm. The requirement for their elite hurdlers is smaller here than on their take off phase. This could be because they are transitioning back to sprinting making this distance even more critical.

### **Summary**

The reviewed research shows that many different variables are involved in the clearance of a hurdle. Many researchers have suggested or stated that the distance to the hurdle at takeoff is the most important of these variables. The researchers do not all agree on what the proper takeoff distance is or how to determine the correct takeoff distance for an athlete, however.

## CHAPTER 3

### METHODS

The purpose of this study was to determine if the relationships between the height of a hurdler and the takeoff distance to the first hurdle for men and women as reported by Frye (2008) were valid for NCAA Division III 100 m and 110 m hurdlers. Frye presented these relationships in tables listing hurdler heights and the corresponding takeoff distances for male and female hurdlers.

#### Participants

Participants in this study were three female 100 m hurdlers and four male 110 m hurdlers all of whom competed on an NCAA Division III institution's varsity track and field team. Table 2 contains the general characteristics of the participants.

Table 2

*Characteristics of Participants*

Participant #	Height (cm)	Weight (kg)	Gender	Days to PR	Age (years)	Hurdle Age (years)	100/110m Race PR (s)
1	182.9	72.7	Male	-4	21	7	15.00
2	162.6	66.1	Male	-4	18	2	16.05
3	160.0	62.8	Male	2	18	4	15.01
4	181.6	78.6	Male	2	18	5	14.75
5	157.5	58.2	Female	-4	22	8	14.96
6	160.0	61.5	Female	2	19	3	16.61
7	170.2	71.5	Female	-19	18	6	17.79

*Note: The days to personal record (PR) for each athlete is expressed as the number of days after data collection that the PR time was achieved. Negative numbers indicate the number of days prior to data collection that the PR time was achieved.*

## **Informed Consent**

The protocol for this research was approved by the SUNY Cortland Institutional Review Board (IRB) prior to collection of any data from human subjects (Appendix A). Each participant completed and signed an informed consent form prior to their participation in this study (Appendix B). The form listed details about the study including the purpose, filming and digitizing procedures, trial protocol, risks and benefits, the ability to withdraw at any time, as well as IRB approval information.

## **Variables**

*Height:* The height of each participant was measured with a stadiometer and was expressed in meters (m).

*Weight:* The weight of each participant was measured with a beam scale and was expressed in kilograms (kg).

*110m or 100m hurdle PR's:* These were taken from the fastest times for the athletes that they have ever run. All of the participants achieved their PR's during the season when data collection occurred. Some of the times were from the same week as the study but others were earlier or later in the season and were expressed in seconds to the hundredth. The dates of the times were also recorded and are located in Table 3 as expressed by how many days from the date of recording they were run.

*Takeoff Distance:* This was measured from the video recorded during the trials for each of the athletes and was expressed in meters (m). The average takeoff distance of each participant's three trials was also computed.

*Predicted Takeoff Distance:* Using Frye's (2008) chart the takeoff and heights were recorded and plotted. Linear regression equations that predicted takeoff distance from height were

determined for each gender using the data from this chart. The height of each participant was entered in the regression equation for their gender to compute the predicted takeoff distance since no participant matched the exact heights given in the chart. Takeoff distances were expressed in meters.

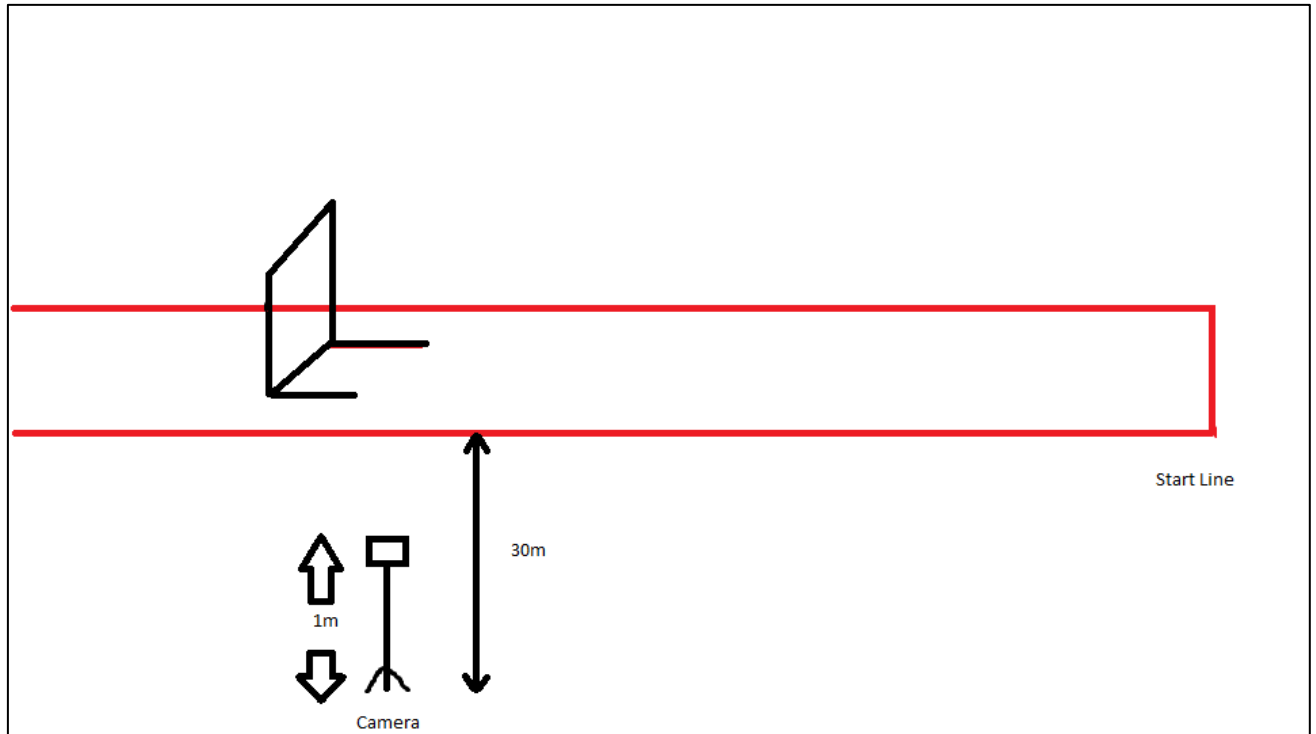
*Percent Difference in the World Record vs. Personal Record (PR):* To compare the PR's of the men and women, the difference between the PR of each participant and the world record for their event was computed and expressed as a percent of the world record.

The independent variables was the percent difference between the world record and the participant's PR. The dependent variable was the difference in the actual takeoff distance and predicted takeoff distance from the hurdle for the athlete and was recorded in meters (m).

### **Data Collection Setup and Procedure**

Participants were video recorded by a JVC GC-PX10 high definition digital fixed view video camera positioned approximately 30 m to the left of the hurdling lane. The camera operated at 60 frames per second and recorded full high definition (1920 x 1080) video. The shutter speed of the camera was set to 1/320 s and the aperture and gain were adjusted for proper exposure. The optical axis of the camera lens was aligned perpendicular to vertical plane passing through the center of the hurdle lane and approximately aligned with the vertical plane of the face of the first hurdle. The camera lens was approximately 1 m high. The fixed field of view of the camera was approximately 17 m wide during the trials of participant 1 and approximately 7 m wide for the trials of all the other participants. The first hurdle was in the center of the width of the camera's field of view. A separate starting line was used for the women to start their trials. The distance to the first hurdle for the men and women is different, as well as the height of the hurdle. A different starting line was used for

the women so that the relative position of the first hurdle would not change. This allowed the reference measurements to remain the same and the position of the camera and of the hurdle in the camera view to remain the same. The position of the camera had the hurdler moving from right to left across the camera's field of view. The camera setup is shown in Figure 1.



*Figure 1.* Data collection set up showing the location of the camera relative to the hurdle and hurdle lane.

Two data collection sessions took place. Data collection session 1 for participant 1 and data collection session 2 for the rest of the participants. The weather on the day of recording was cloudy and 51 degrees during data collection session 1 and 55 degrees and cloudy during data collection session 2. Session 1 began at noon while session 2 began at 4:15 pm on the same day. Data collection occurred two days prior to the conference championship meet. The participants' training plan for the outdoor season was designed to

cause the athletes to peak at this conference championship meet. For participants 2, 3, 6, and 7 this was the last week of their season. Participants 4 and 5 had two more weeks of their season while participant 1 had three more weeks. The difference in season ending dates was due to the different competitions the participants had qualified for in the weeks following the conference meet.

Each of the participants warmed up using the high hurdle warm up routine described in Appendix C. This was the normal warm up routine that they completed on any days that they hurdled throughout the season. They were monitored during their warm up and given feedback from coaches as in a typical practice session. Feedback included adjustments to the takeoff distances of the athletes as well as other corrections to their run. Participants were also instructed to treat each experimental trial like a race and to run at 100% effort. The participants were then instructed to do a practice repetition before the filming began. Each participant then ran three separate trials over the course of one practice session on a 400 m outdoor track. A trial consisted of approximately the first 25 m of a hurdle race, from the starting blocks and then over the first hurdle and second hurdle. Participants sprinted eight steps to the first hurdle and three steps between the first and second hurdle. Between trials, participants had at least four minutes of recovery time. Four minutes was considered to be enough time for the energy systems stressed in a trial to be fully recovered. Participants were instructed to stay warm and loose between the trials as they would in a typical hurdle practice session. Each trial in which the participant successfully cleared the hurdle was used in this study. The only participant that did not successfully clear the hurdle in three trials was participant 7. After a four minute rest, this participant then ran a fourth trial. This trial was successful and data from this trial was used in this study.



Immediately before and after each data collection session, the video camera recorded a 5 m reference measure for use in the data reduction. Hemispherical markers were placed in the center of the hurdling lane 2.5 m before the first hurdle and 2.5 m after the first hurdle to produce a reference length of 5 m between the two markers. After the video was recorded and prior to any trials, the markers were removed from the hurdling lane.

Recording of the trials in each session began when the subject for the first trial of a session entered the starting blocks. The camera recorded continuously throughout the data collection session until the last trial was completed. This resulted in multiple 4.18 GB video clips due to the restrictions of the camera to record more than 4.18 GB in one video clip. The multiple 4.18 GB video clips recorded in a session were continuous, however, so there was no loss in data. In other words, the last video frame in one clip was followed with no time loss by the first video frame in the next clip. If two consecutive video clips were joined the video would show no break at the juncture between the two clips.

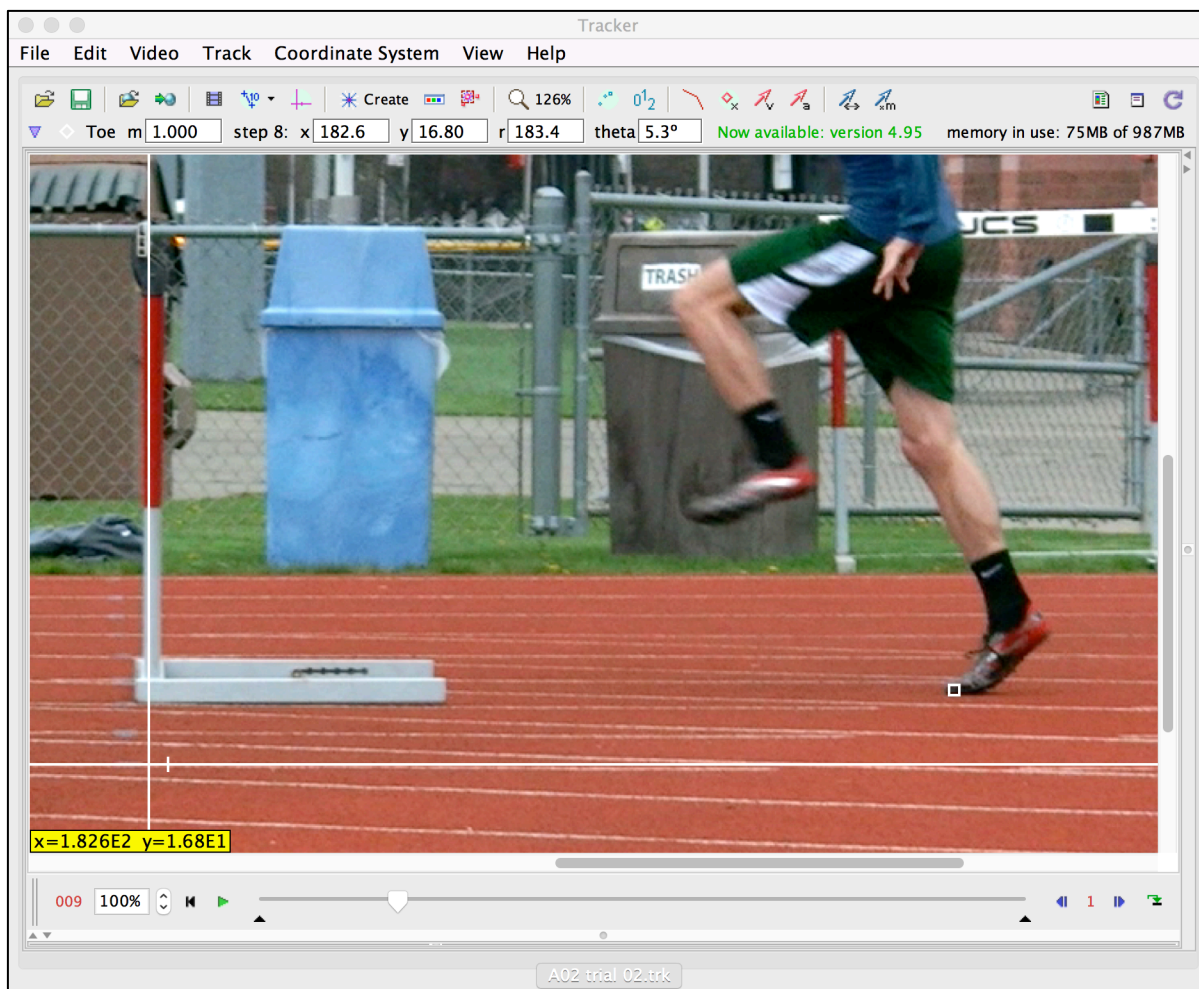
### **Data Reduction**

The video clips recorded during data collection were edited to produce single video clips of each trial of each subject as well as separate video clips of the reference measure. Participants were assigned numbers and the video clips and data files were identified by participant number only. Participants' names were not linked with any video or data files.

The "Tracker" video analysis software was used to measure the hurdle takeoff distances from the video clips of each of the participants' three trials. First, the video clip of the reference measure was opened in the Tracker software. A calibration stick was then created and its ends were placed on the two markers that defined the 5 m reference measure in the hurdle lane. The length of the calibration stick was then set to 500 cm. The calibration

stick transformed all linear distance measurements from the video window from pixels to real life units.

The video clip of the first trial of participant 1 was then opened in the Tracker software and the 500 cm calibration stick was imported into this analysis. A Cartesian coordinate system was created in the Tracker video window with the x-axis aligned parallel to the hurdling lane and the y-axis aligned with the front face of the hurdle so that the x-coordinate of the front face of the hurdle was 0.0 cm. A point mass was then created in Tracker and labeled as “toe”. To measure the takeoff distance, the video was then advanced until just before takeoff of the takeoff foot. The cursor was then placed over the toe of the takeoff foot and this point was digitized as the “toe”. Since the x-coordinate of the hurdle face was 0.0 cm, the x-coordinate of the “toe” was the takeoff distance to the hurdle. This distance was entered into the data file as the takeoff distance for that subject and trial. For subsequent trials, the coordinate system, calibration stick, and point mass were imported to Tracker along with the video clip of the trial to be analyzed. The procedure used to measure and record the takeoff distance was then repeated. A screen shot of the Tracker software is shown in Figure 2. The x and y axes are shown in the video screen and the box marking the digitized takeoff foot toe is also shown. The x and y coordinates of the takeoff foot toe are shown in the information bar just above the video window in Tracker and also in lower left corner of the video window in Tracker window.



*Figure 2.* The Tracker screen showing the video window, the x and y coordinate axes, digitized toe, and toe coordinates. The value for x-coordinate of the toe is the takeoff distance in cm.

### Statistical Analysis

The average takeoff distances for each athlete were calculated using the three trials of each participant. The predicted takeoff distances were computed for each participant using the participant's height in the linear regression equation which predicted takeoff distance from height based on data in Frye's (2008) chart. The difference in the actual and predicted takeoff distances were then computed and recorded. The personal record times (PR's) of the participants in the 100 m or 110 m hurdles were determined and recorded. The PR's for all of the participants were achieved in the 2016 outdoor track and field season. Information on

how when the PR's occurred relative to the day of filming were then determined (refer to Table 3). The participant's PR times were compared to the world record for their event by computing the difference between the PR and the world record and expressing this difference as a percent of the world record. At the time this research was completed, the men's 110 m hurdles world record was 12.80 s and the women's 100 m hurdles world record was 12.20 s. The women's 100 m hurdles world record was set after more than two months after data collection but prior to data analysis. The percent difference from the world record allowed a direct comparison between male and female participants. Separate correlation coefficients were calculated for men and women between the difference in predicted and actual takeoff distances and percent difference from the world record.

## CHAPTER 4

### RESULTS

The purpose of this study was to determine if the relationships between the height of a hurdler and the takeoff distance to the first hurdle for men and women as reported by Frye (2008) were valid for NCAA Division III 100 m and 110 m hurdlers.

#### **Results for Male Participants**

Participant 1 was the tallest of all the participants at 1.88 m. His predicted takeoff distance was 2.17 m which was the closest of all the male participants. His three trials produced takeoff distances of 1.86 m, 1.82 m, and 1.80 m for an average takeoff distance of 1.83 m. The difference in his predicted and actual takeoff distances was 0.34 m. His PR of 15.00 s in the 110 m hurdles was 17.2% slower than the world record of 12.80 s for the event. Participant 1 had the second fastest 110 m hurdles PR of the male participants.

Participant 2 was the second tallest participant at 1.84 m. His predicted takeoff distance was 2.19 m, just 0.02 m less than Participant 1. His three trials had the largest range with a 0.183 m difference between the closest takeoff distance and the furthest takeoff distance. His average takeoff distance was 1.80 m and was the closest average takeoff distance among the male hurdlers. The difference in his predicted and actual takeoff distances was 0.39 m. His PR of 16.05 s in the 110 m hurdles was the slowest of the male participants and was 25.4% slower than the world record. Participant 2 had the largest difference from his predicted and actual takeoff distances out of all the participants.

Participant 3 was the shortest of the male participants at 1.70 m. His predicted takeoff distance the furthest away out of any participant at 2.26 m. His average takeoff

distance was the furthest away out of the participants at 1.96 m. The difference in the predicted and actual takeoff distances was 0.30 m which was the same as Participant 4's and was the smallest difference among all the participants. Participant 3's PR for the 110 m hurdles was 15.01 s (only .01s slower than participant 1's PR) and was 17.3% slower than the world record.

Participant 4 was 1.80 m tall. His predicted takeoff distance was 2.21 m. His average takeoff distance was 1.91 m for a difference of 0.30 m. This difference is the same as participant 3's and these two participants had the smallest difference between predicted and actual takeoff distances. Participant 4's PR for the 110 m hurdles was 14.75 s which was the fastest of any participant and was 15.2% slower than the world record.

The difference between men's predicted and actual takeoff distances and the percent difference between their PR's and the world record were strongly correlated:  $r(2) = .921$ .

### **Results for Female Participants**

Participant 5 was the shortest female at 1.62m. Her predicted takeoff distance was 2.00 m which was the furthest out of the females. The average takeoff distance for her three trials was 1.69 m with a range of 0.153m. The difference in her predicted and actual takeoff distances was 0.31 m which was the largest difference of all the females. Her PR for the 100 m hurdles was 14.96 s which was the fastest among the female participants and was 22.6% slower than the world record.

Participant 6 was the tallest of the female participants at 1.711 m. Her predicted takeoff distance was the closest of all the females at 1.94 m. Her trials had the largest range in takeoff distance among the females with a 0.174 m difference between her closest takeoff

and furthest takeoff. Her average takeoff distance was 1.70 m for a difference of 0.24 m between predicted and actual takeoff distances. The 0.24 m difference was the smallest of all the female participants. Her PR for the 100 m hurdles was 16.61 s which was 36.1% slower than the world record.

Participant 7 was 1.697 m tall. Her predicted takeoff distance was 1.95 m, only 0.01m larger than participant 6's. Her takeoff distances had a range of 0.141m from her furthest takeoff to her closest takeoff. Her average takeoff distance was 1.67 m which was the closest of all the female participants and represented the second largest difference in predicted versus actual takeoff distances among the female participants at 0.28 m. Her PR for the 100 m hurdles was 17.79s which was 45.8% slower than the world record.

The difference between the women's predicted and actual takeoff distances and the percent difference between their PR's and the world record were negatively correlated:  $r(1) = -.474$ .

A summary of the results for each participant and each trial is shown in Table 3. Participants 1-4 are men and participants 5-7 are women.

Table 3

*Results for All Participants and Trials*

Participant #	Trial 1 TO (m)	Trial 2 TO (m)	Trial 3 TO (m)	Average TO (m)	Predicted TO (m)	Predicted – Avg TO (m)	PR-WR %
1	1.856	1.825	1.798	1.83	2.17	.34	17.2%
2	1.698	1.826	1.881	1.80	2.19	.39	25.4%
3	1.969	1.974	1.93	1.96	2.26	.30	17.3%
4	1.952	1.856	1.913	1.91	2.21	.30	15.2%
5	1.791	1.638	1.639	1.69	2.00	.31	22.6%
6	1.699	1.616	1.790	1.70	1.94	.24	36.1%
7	1.638	1.749	1.608	1.67	1.95	.28	45.8%

### **Combined Results**

In order to examine the combined results of the male and female participants, the percent difference between the participants' PR's and the world records were utilized. The male participants were 15.2%, 17.2%, 17.3%, 25.4% slower than the men's world record while the females were 22.6%, 36.1%, and 45.8% slower than the women's world record. The results for the females and males were very different. When the data were combined, the difference between the predicted and actual takeoff distances and the percent difference between the participants' PR's and the world records were negatively correlated:

$$r(5) = -.443.$$



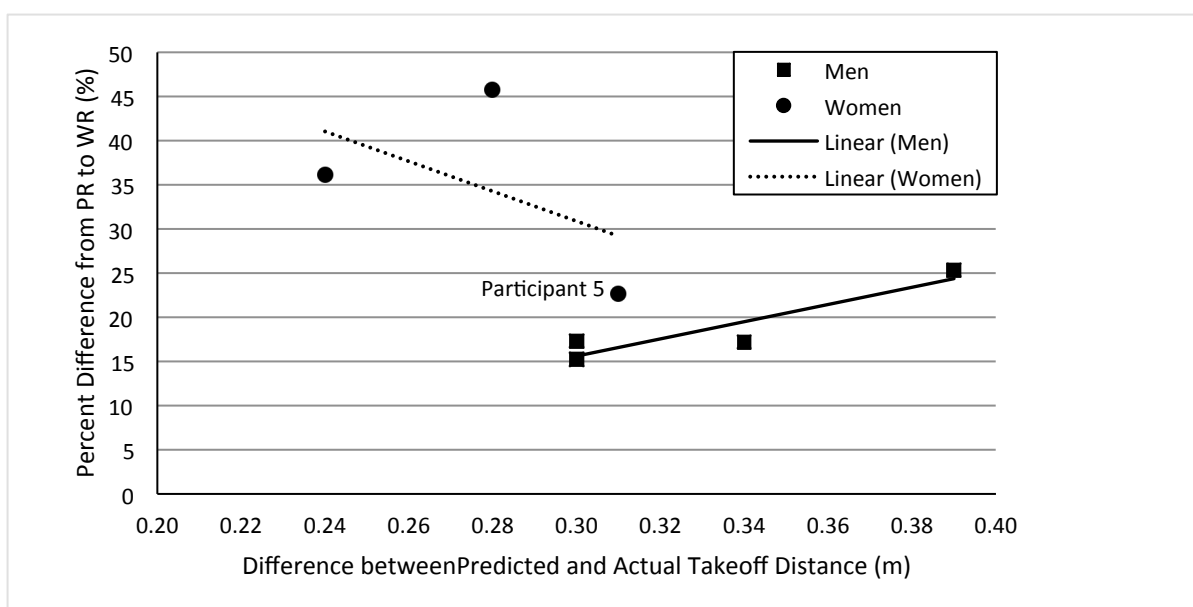
## CHAPTER 5

### DISCUSSION AND CONCLUSION

The purpose of this study was to determine if the relationships between the height of a hurdler and the takeoff distance to the first hurdle for men and women as reported by Frye (2008) were valid for NCAA Division III 100 m and 110 m hurdlers.

#### **Discussion and Recommendations**

For the male participants, there was a strong correlation ( $r = .921$ ) between the difference in predicted and actual takeoff distances and the percent difference between the participants' PR's and the world records. This contrasted with the weak and negative correlation ( $r = -.474$ ) for the same two variables for the women participants. One possible reason for the difference between the results for the men and women could be the difference in hurdling ability between the male to the female participants in this study. The men's PR's were as close as 15.2% to the world record and only as far as 25.4% from the world record. However, the women were only as close at 22.6% to the world record and as far as 45.8% away from the world record. Also, three of the four male participants were ranked in the top 75 in the 2016 NCAA Division III rankings for the 110m hurdles while only the fastest female was ranked in the top 75 in the 2016 NCAA Division III rankings for the 100m hurdles. This shows that the women in this study were not nearly as fast, comparatively, as the men. Only the fastest female, participant 5, was even close to the same percentage as the men and is only slightly better, relatively, than the slowest male. Figure 3 shows this difference when the men and the women are plotted together.



*Figure 3.* Difference between predicted and actual takeoff distances vs. percent difference in PR to world record for men and women participants.

Female participant 5 clearly aligns closer with the males in this study shown by her data point being close to their linear trend line in Figure 3. If participant 5 is added to the male participant data set, the correlation between the difference between predicted and actual takeoff distances and percent difference between PR and world record becomes slightly weaker than for males only. The correlation falls from .921 to .709. While this is still a much stronger correlation than all the participants combined it weakens the correlation for the male only group slightly.

Another possible explanation for the large difference in results for the men and the women could lie in their overall ability, or more specifically, in the horizontal velocity that they can produce. Mann (2011) stated that hurdlers need to be able to produce a certain minimal velocity in order for the hurdle clearance to be successful. Mann (2011) only studied what he qualified as ‘elite’ hurdlers, or hurdlers that competed internationally. It is

assumed that the horizontal velocities that he lists are instantaneous velocities of the center of mass at the takeoff of the athlete into the hurdle. While horizontal velocity was not measured in the present study, it is assumed, based on their PR's, that the participants were not able to produce the minimal horizontal velocity stated by Mann (2011).

The height of the women in this study compare better to the world top ten hurdlers in 2016 for this event than the men do. According to Track & Field News (100 Hurdles- OG Not Required, 2017), the average height of the top ten women hurdlers in 2016 was 1.70 m while the average height of the women in this study was 1.68 m. The top ten hurdlers in the world in 2016 for the men had an average height of 1.86 m (110 Hurdles- It's Jamaica's First, 2017) while the men in this study had an average height of 1.80 m. The average height of the men in this study was .06 m shorter than the average height for the top men hurdlers in the world in 2016 while average height of the women in this study was only .02 m shorter than the top women hurdlers in the world in 2016. The average height for the women was brought lower by participant 5 who was only 1.62m tall. The range of heights for the top 10 women hurdlers in 2016 was 1.63 m to 1.78 m, and participant 5 was the only female participant whose height fell outside of this range. The top ten men hurdlers in the world range in height from 1.78 m to 1.96 m and participant 3 was only 1.70 m tall. Participant 3 was the only male participant whose height fell outside of this range. With the exception of participants 3 and 5, the heights of the participants were well within the range of heights for 'elite' level hurdlers.

There was also much less variation in the PR times of the male participants in this study. The PR times of the male participants for the 110 m hurdles ranged from the fastest at 14.75 s to the slowest at 16.61 s for a range of only 1.86 s. The PR times of the female

participants for the 100 m hurdles ranged from the fastest at 14.96 s to the slowest at 17.79 s for a range of 2.83 s. This larger range of abilities for the female participants along with their slower PR's when compared to the world record suggest that the female participants were less 'elite' than the male participants and could not produce a fast enough horizontal velocity over the hurdle for Frye's (2008) chart to apply to them.

Another consideration is the difference between multi-event athletes and hurdle specialists. All of the females in this study were multi-event athletes, as were male participants 1 and 2. In general, the hurdling ability level of multi-event athletes is considered lower than that of hurdle specialists (Čoh and Iskra, 2012; Lindeman, 2008; McFarlane, 1993).

## **Conclusion**

Recommended takeoff distance for a hurdler can easily be determined by a coach. With the regression equation derived from Frye's (2008) data, the height of an athlete can be used to compute the recommended takeoff distance. However, it is unclear if hurdlers need to be at an elite level for this chart to apply or if they need to be able to produce a certain minimal velocity. The difference between the men and the women in this study also suggests that more research needs to be done to further explore the validity of this chart for each gender.

In conclusion, the data suggest that this chart is plausible for NCAA Division III male hurdlers but more research with more participants is needed in order for a clear distinction to be made. The data also suggest that the Frye's chart (2008) works better for male hurdlers than females. It is also possible that the athletes need to achieve a certain minimum level of velocity in order for this chart to work. With only seven total participants the relationships

are not strong enough to accept the hypothesis. Including athletes of a larger range of abilities may help to determine a base value of ability for which this chart applies.

## References

- 100 Hurdles- OG Not Required. (2017, February). *Track and Field News*, 46.
- 110 Hurdles- It's Jamaica's First. (2017, February). *Track and Field News*, 20.
- Čoh, M. & Dolenec, A. (1996). Three-dimensional kinematic analysis of the hurdles technique used by Brigita Bukovec. *New Studies in Athletics*, I(1), 63-69.
- Čoh, M. & Iskra, J. (2012). Biomechanical studies of 110 m hurdle clearance technique. / Biomehanička istraživanja tehnike kvalitete prelaska prepone u trčanju na 110 m. *Sport Science*, 5(1), 10–14.
- Finch, A., Ariel, G., & McNichols, J. (2000). Integrated kinematic data analysis of American elite hurdlers. In *ISBS-Conference Proceedings Archive* (Vol. 1, No. 1).
- Frye, C. (2008). The high hurdles: How to achieve fast times. Retrieved from <http://www.usatf.org/groups/coaches/library/2008/Hurdle/CurtisFrye.pdf>.
- Grimshaw, P., Marar, L., & Salo, A. (1995). Biomechanical analysis of sprint hurdles. *Athletics Coach*, 29(2), 5-7
- Hay, J. G. (1985). *The biomechanics of sports techniques*. (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
- Hitchcock, H. C. (1989). Recovery of short-term power after dynamic exercise. *Journal of Applied Physiology*, 67(2), 677-681.
- Lindeman, R. (2008). 110 meter hurdle technique and theory. Texastrack.com, 2008. Retrieved from [http://www.texastrack.com/coaching\\_article\\_2.htm](http://www.texastrack.com/coaching_article_2.htm).
- Mann, R. V., & Herman, J. (1985). Kinematic analysis of Olympic hurdle performance: women's 100 Meters. *International Journal of Sports Biomechanics* 1, (1), 163–173.

- Mann, R. V. (2011). *The mechanics of sprinting and hurdling*. (2011th ed.). Las Vegas, NV: Author.
- Mauroy, G., Schepens, B., & Willems, P. A. (2014). The mechanics of jumping over an obstacle during running: a comparison between athletes trained to hurdling and recreational runners. *European Journal of Applied Physiology*, 114(4), 773-784.
- McDonald, C. & Dapena, J. (1991a). Linear kinematics of the men's 110-m and women's 100m hurdles race. *Medicine & Science in Sports & Exercise*, 23, 1382-1391.
- McDonald, C. & Dapena, J. (1991b). Angular momentum in the men's 110-m and women's 100-m hurdles races. *Medicine & Science in Sports & Exercise*, 23, 1392-1402.
- McFarlane, B. (1988). *The science of hurdling*. Athletics Canada.
- McFarlane, B. (1993). Biomechanics of hurdling reviewed. *Modern Athlete and Coach*, 31(3), 31-35.
- Ross, W, L. & Hernandez de Ross, N. F. (1997). The Hurdler's Bible 2.
- Salo, A., Grimshaw, P. N., & Viitasalo, J. T. (1997). Reliability of variables in the kinematic analysis of spring hurdles. *Medicine & Science in Sports & Exercise*, 29(3), 383-389.
- Salo, A., Grimshaw, P. N. & Viitasalo, J. T. (1999). The use of motion analysis as a coaching aid to improve the individual technique in sprint hurdles. In: *Proceedings of the XVII ISBS Symposium. School of Biomedical and Sports Science* (pp. 57-60). Edith Cowan University, Perth, Western Australia: , pp. 57-60.
- Winckler, G., Shaver, D., & Schexnayder, B. (2003). *USA Track and Field Coaching Education Program Level II Course- Sprints, Hurdles, Relays*.

Tidow, G. (1997). Model technique analysis sheets for high hurdlers. In J. Jarver (Ed.), *The hurdles: Contemporary theory, technique and training* (3<sup>rd</sup> ed.) (pp. 57–66).

Mountain View, CA: Tafnew Press.

Winckler, G. (1994). Practical Biomechanics For the 100m Hurdles. Presented at the USA Track and Field Heptathlon Summit, November 1994. Retrieved from <http://elitetrack.com/articles/articles-read-2190/>.



## Appendix A

### SUNY Cortland Institutional Review Board Approval Letter

#### MEMORANDUM



To: Phillip Wiltshire  
Peter McGinnis

From: Jena Curtis, Chair  
Institutional Review Board

Date: 5/2/2016

RE: Institutional Review Board Approval

In accordance with SUNY Cortland's procedures for human research participant protections, the protocol referenced below has been approved for a period of one year:

**Title of the study:** A Test of the Validity of Height as a Determinant of Takeoff Distance for Hurdle One for Division 3 Hurdlers

<b>Level of review:</b> Expedited	<b>Protocol number:</b> 151648
-----------------------------------	--------------------------------

<b>Project start date:</b> Upon IRB approval	<b>Approval expiration date*:</b> 5/1/2017
--	--

**\* Note:** Please include the protocol expiration date to the bottom of your consent form and recruitment materials.

For more information about continuation policies and procedures, visit

[www.cortland.edu/irb/Applications/continuations.html](http://www.cortland.edu/irb/Applications/continuations.html)

The federal Office for Research Protections (OHRP) emphasizes that investigators play a crucial role in protecting the rights and welfare of human subjects and are responsible for carrying out sound ethical research consistent with research plans approved by an IRB. Along with meeting the specific requirements of a particular research study, investigators are responsible for ongoing requirements in the conduct of approved research that include, in summary:

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals' participation in the research, unless these requirements have been waived by the IRB;
- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to [irb@cortland.edu](mailto:irb@cortland.edu) within three days);
- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- following the principles outlined in the Belmont Report, OHRP Policies and Procedures (Title 45, Part 46, Protection of Human Subjects), the SUNY Cortland College Handbook, and SUNY Cortland's IRB Policies and Procedures Manual;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.

Miller Building, Room 402 • P.O. Box 2000 • Cortland, NY 13045-0900

Phone: (607) 753-2511 • Fax: (607) 753-5590

Institutional Review Board  
Page 2

In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email [irb@cortland.edu](mailto:irb@cortland.edu) or by telephone at (607)753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology, visit <http://www.cortland.edu/irb/members.html> to obtain a current list of IRB members.

Sincerely,

A handwritten signature in black ink, appearing to be 'Jena Curtis', with a stylized flourish at the end.

Jena Curtis, Chair  
Institutional Review Board  
SUNY Cortland

## Appendix B

### Informed Consent Document

You are being asked to take part in a research study on hurdling technique. The purpose of the study is to determine if the height of a hurdler is related to the takeoff distance to the first hurdle as described by Curtis Frye (2008), a well respected hurdling coach. This study may help determine if the relationship between hurdler height and takeoff distance as presented by Coach Frye is valid for NCAA DIII hurdlers.

If you decide to participate in this study, you will be videotaped during practice in the week prior to the SUNYAC Championship meet. You will not have to deviate from your normal practice routine in order to be take part in this study. During the hurdling practice when data is collected, your height and weight will be measured and recorded. You will then complete your normal warm up routine. You will be asked to start in starting blocks and run as fast as you can over the first and second hurdle. You will do this three times with a full recovery of at least 4 minutes between each trial. A video camera will record you going over the first hurdle in each trial. Your takeoff distances will be measured from the videos of each trial. At the subsequent SUNYAC Championship meet, your fastest hurdling time in the heats or finals of that competition will be noted.

The risks that you can expect from participating in this study are the same ones that you would assume in a normal practice where you are sprinting and hurdling at full speed. These risks include any injuries that you might sustain and fatigue. Athletic trainers will be available inside Park Center for the treatment of any injuries that may be obtained. Another risk is breach of confidentiality. To avoid this, the video records, takeoff distance, and height and weight information will be stored on the researcher's password protected computer in his office and any data recorded on paper will be stored in a locked cabinet in the researcher's office. Your data will be coded so that your name is not associated with the data. Only the researcher will have the key that links your name to the code.

The benefit that you can expect from participating in this study is a better understanding of the proper takeoff distance for you at hurdle one. There is no penalty for refusing to participate in this study. You may also withdraw from this study at any time without penalty.

If at any time, you have questions about the study, please contact the researcher, Phillip Wiltshire, by phone (607-344-1921) or by email ([phillip.wiltshire@cortland.edu](mailto:phillip.wiltshire@cortland.edu)).

This study has been approved by the Institutional Review Board at SUNY Cortland. For more information about research at SUNY Cortland or information about the rights of research participants, please contact the Institutional Review Board by phone (607-753-2511) or by email ([irb@cortland.edu](mailto:irb@cortland.edu)).

I, \_\_\_\_\_, have read the description of the project for which this consent is requested, I understand my rights, and I hereby consent to participate in this study.

Signature \_\_\_\_\_

Date \_\_\_\_\_

## Appendix C

### High Hurdle Warm-Up

1. 400 Meter Jog
2. Walks (2 x 20m of each):
  - Toe Walks
  - Heel Walks
3. Circles: Hips, Arms, & Ankles (20 of each)
4. Static Flexibility: 3 x 15 seconds of the 'middle hamstring stretch'
5. Movement Preparation:
  - 2 x 20m of Trail Leg Skips (each Side)
  - 2 x 20m of Straight Leg Shuffle
  - 2 x 20m of Side Jacks
  - 2 x 20m of Backwards 'T' Walks
6. Dynamic Flexibility:
  - Scorpions: 20 touches each side
  - Eagles: 20 touches each side
  - Leg Swings: 20 in each direction
7. PNF Stretch – Hamstring Group (3 cycles of static/contract)
8. Sprint Technique (2 x 20 meters each/walk back):
  - Frankensteins (every step)
  - A Skip
  - High Knees
  - B Skip
9. Hurdle Walk-Overs (2 sets of 6 at 30"/36"):
  - Forward, Backward, Right, and Left
10. Stationary Trail Leg Drills: 2 Sets of 15 Reps SLOWLY
11. Technique (2 sets of 5-stepping four hurdles at 30'/35' – full height):
  - Lead Leg, Trail Leg, Over the Top
12. Quick Steps (@ ½ Distance): 4 x 4 hurdles 3" low
13. One-Steps 4 x 4 hurdles @ 30"/36" height
14. Strides: 4x Gradually build up into 15 good hard steps/walk back
  - In spikes

**Appendix D**  
Frye's (2008) Original Chart

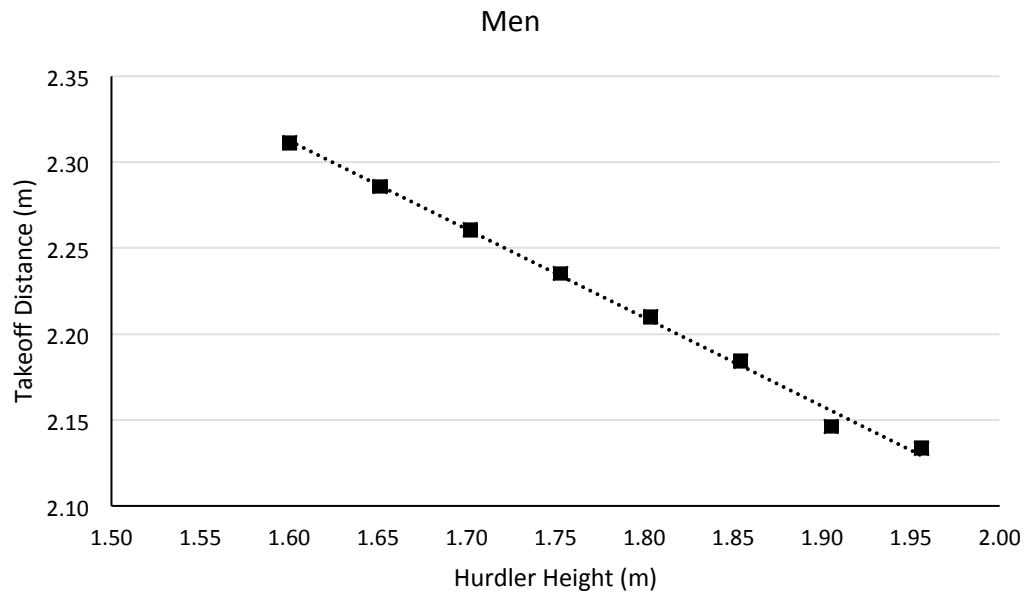
Table 4.

*Reproduction of Frye's (2008) Original Chart of "Model Takeoff Distance"*

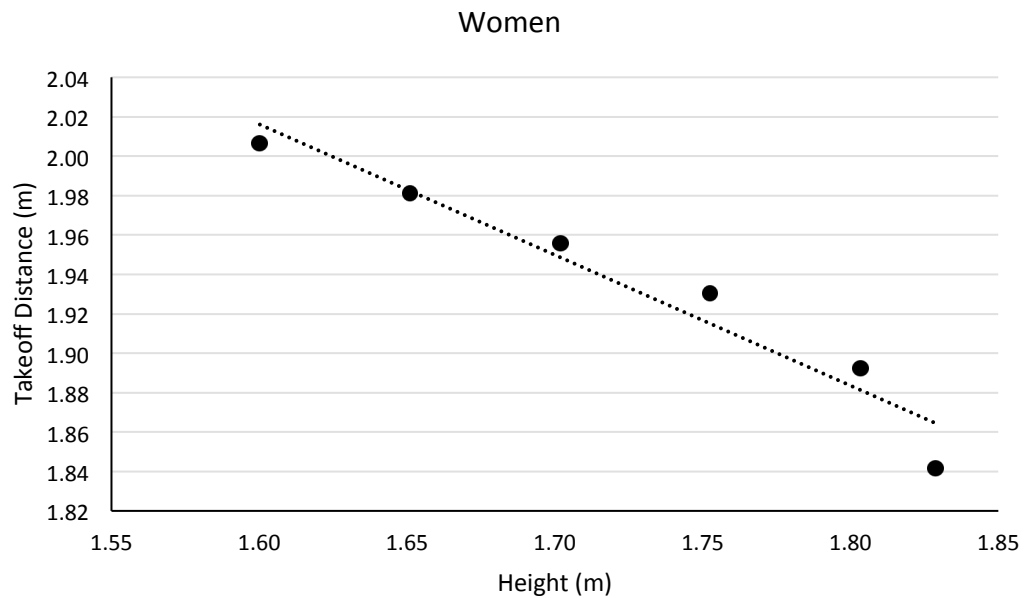
Males		Females	
<b>Height (ft/in)</b>	<b>Takeoff (ft/in)</b>	<b>Height (ft/in)</b>	<b>Takeoff (ft/in)</b>
5'3"	7'5"-7'9"	5'3"	6'5"-6'9"
5'5"	7'4"-7'8"	5'5"	6'4"-6'8"
5'7"	7'3"-7'7"	5'7"	6'3"-6'7"
5'9"	7'2"-7'6"	5'9"	6'2"-6'6"
5'11"	7'1"-7'5"	5'11"	6'0"-6'5"
6'1"	7'0"-6'10"	6'0"	5'10"-6'3"
6'3"	6'10"-7'3"		
6'5"	6'10"-7'2"		

## Appendix E

### Frye's (2008) Chart Entries Plotted



*Figure 4.* Takeoff distance versus hurdler height for men hurdlers based on values derived from Frye's (2008) chart.



*Figure 5.* Takeoff distance versus hurdler height for women hurdlers based on values derived from Frye's (2008) chart.